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CONSEQUENCES OF USING LNG AS A MARINE FUEL

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Abstract

The paper presents the consequences of LNG usage as a marine fuel. The restrictions of harmful substances emission to atmosphere from marine engines, especially in controlled emission areas (ECA and SECA areas) of nitrogen oxides and sulfur oxides, forces the engine makers to use additional installations, which operation may fulfill the purification requirements of exhaust gases. The option is a usage gaseous fuels, especially liquid natural gas (LNG) or compressed natural gas (CNG). There is no an alternative – only gaseous fuels may fulfill the Tier3 level without exhaust gases purification process. In prognosis about 650 ships (in high scenario about 2000) will be fuelled LNG in the year 2025. It was written why the liquid fuels stay unattractive. The basic problem is still the limited network of LNG distribution in ports and the lack of small vessels or barges for LNG bunkering. The proposition of design of LNG tank and barges were presented. The next problem is a deficiency of LNG bunker port in deep sea before entering the ECA areas. The controlled emission areas will extend in the near future. The LNG or CNG seemed to be the preferring fuel in industry due to CO_2 emission limits and environmental taxes. The demand for LNG in prognosis to 2025 in bunker ports varies 0.1-18% of total fuel bunker depending on legislation and low or high case, in base case it will be 3%. It depends on the conviction of ship-owners that is no return from transition to the LNG or CNG ship fuelling. The examples to LNG ship conversion were described.

Keywords: *marine fuel, ships propulsion, LNG, CNG, natural gas, atmosphere protection*

1. Introduction

The environment contamination from sea transport has a 4-8% level. The atmosphere protection from exhaust gases coming from engines of sea transport is a necessity due to annex VI of Marpol Convention. According to IMO regulation from January 1st, 2012 the sulphur content in HFO ought to be less than 3.5% and will decrease in the next years up to below 0.5%. On the SECA areas from January 1st, 2015 the sulphur content in marine fuels would be less 0.1%. If the bunker fuel has over 0.1% the scrubbers will be used. From January 1st, 2016 the Tier III demand will be in force, it means reduction of NO_x approximately 75% below the Tier II level [1-3].

The use of conventional fuel (high-sulphur) is limited if ship's systems are not equipped in after burning treatment measures like SCR or other purification. On SECA areas it is a necessity to change at first on low-sulphur HFO (<1%S) and next in ports and canals on low-sulphur MDO (<0.1%S). It means that ships ought to have on board minimum three types of fuel. If it is known that the systems for different fuels ought to be independent it provides for dividing the fuel systems into parts and complicates the operating process. It must be remembered about the fuel quantity in daily tanks which ought to be used before entering the SECA areas or change the valves on daily tanks for filling of low-sulphur fuel if there are independent daily tanks for different fuel types. The position of ship ought to be notified to make sure that the legislation requirement is fulfilled.

The new international legislation on maritime engines emissions on years 2010-2020 is presented in Tab. 1.

Tab. 1. The international legislation of emissions from marine engines on years 2010-2020

Enforcement	Reference	Legislation	Legislator	Area	Target	Consequences	Typical option for fullfilment
01.01.2010	2005/33/EC	Sulphur content <0.1% when at berth in EU harbours and in canals	EU	EU	Sailing and new ships	Possible equipment adaption	- change to 0.1% S in bunkers at berth and canals; - use LNG as fuel.
01.07.2010	IMO Annex VI	Sulphur content <1% on SECA's	IMO	SECA	Sailing and new ships	Possible equipment adaption or exhaust gases purification	-Use bunkers <1%S; - use bunkers >1%; together with scrubbers - use LNG as fuel.
01.01.2011	IMO Annex VI	Reduction of NOx to Tier II level	IMO	Global	New ships	Choice of special engines or exhaust gases purification	- choose low NOx engines; - use Tier I rated engines and NOx treatment; - use LNG as fuel.
01.01.2012	IMO Annex VI	Sulphur content <3.5% progressively towards 0.5% by 2020	IMO	Global	Sailing and new ships	Higher voyage costs due to fuel price	- low-sulphur fuel or conventional fuel with scrubber is required; - use LNG as fuel
01.01.2015	IMO Annex VI	Sulphur content <0.1% on SECA's	IMO	SECA	Sailing and new ships	Possible equipment adaption or exhaust gases purification	- use fuel <0.1%S or conventional fuel with scrubber is required; - use LNG as fuel.
01.01.2016	IMO Annex VI	Reduction of NOx to Tier III level on ECA's	IMO	ECA	New ships	Exhaust gases purification	- exhaust gases purification or other measures; - use LNG as fuel.

As a result more work time for engine crew. The ship fuel systems are not ready for such operating procedures so it provides to many problems. What remedy is for that? As it is shown in Tab.1 it is a use of LNG as marine fuel and consequently use only this type of fuel [2, 9].

2. Conventional fuel becomes unattractive

Lately the price of LNG is attractive taking into account the heat equivalent. It is about 50-80% of HFO price in USA. Preparing the gas fuel it must be remembered that the energy required to produce LNG varies from 10-20% of the energy content of the natural gas liquefied, depending on composition of the input gas, liquefaction technology and plant size. Preparing the CNG the energy requires to compress natural gas to CNG (18-21 MPa) varies 2-5% of the energy content of the gas being compressed. The volume of CNG is about 250% of LNG volume comparing the heat equivalent and about 500% of HFO. Production, transport and handling of LNG can be more complex and expensive than handling of CNG. The long storage of LNG is a problem due to a necessity of using re-liquefaction systems and costs. Although these disadvantages LNG and CNG are attractive because it is possible to fulfil the Tier 3 level requirements. The LNG/FO emission comparison was shown in Tab. 2.

The LNG/CNG as a marine fuel is an alternative, less costly. LNG is solution to the challenge of cleaner shipping fuels, for trade in Northern Europe and other SECA areas. The technical and operational viability of LNG as a marine fuel has already been demonstrated in Norway, where a number of coastal ferries have operated on LNG for several years. The LNG supply chain has checked in Japan, where some small vessels have been prepared as bunker ships for fuelling other ships or onshore power plants. The logistics of LNG is often mentioned as a reason why LNG-fuelled ships will be difficult to implement even in USA. Only 5 terminals in USA are intended as receiving terminals for LNG carriers and none could provide LNG to a vessel for fuel, however, most of existing terminals in USA have tanker truck loading capability. The tanker truck carries only about 55 m^3, so this is not good way for bunkering the ship [5, 6, 12].

Tab. 2. The LNG/FO emission comparison

Fuel type	SO_x [g/kWh]	NO_x [g/kWh]	PM [g/kWh]	CO_2 [g/kWh]
HFO 3.5%S	13	9-12	1.5	580-630
MDO 0.5%S	2	8-11	0.25-0.50	580-630
MGO 0.1%S	0.4	8-11	0.15-0.25	580-630
LNG	0	2	~0	430-480

The next problem needed to be solved of LNG fuelling is the final cost of LNG delivered to the vessel. This is the major factor killing a number of European LNG fuelled vessel studies. The cost of LNG delivering is the challenge for Northern European ports on existing SECA areas. The LNG availability was shown on Fig. 2.

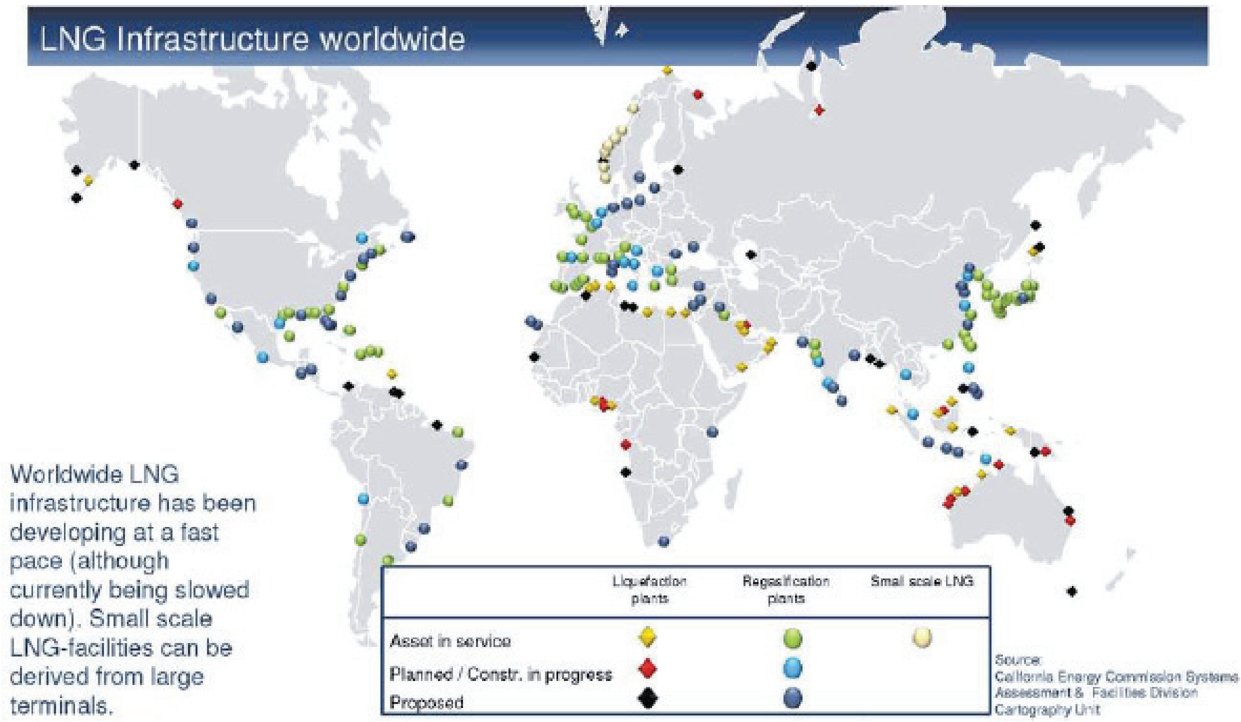

Fig. 2. Worldwide LNG availability [10]

What will happen in the future? LNG is only one way for deep sea shipping to comply future emission regulations. The LNG demand for ship bunkering depends on many different factors. It was prepared some prognosis [11] in three levels: low case, base case and high case. There are big differences among the mentioned cases and the conclusions of LNG demand may be different from the quick LNG growth to the LNG decline about zero. It is a necessity to provide annual updates of the forecasts of LNG fuelled new built ships and LNG bunker demand. The prognosis up to 2025 about global bunker consumption versus LNG bunker demand was presented on Fig. 3 in base case [7, 11].

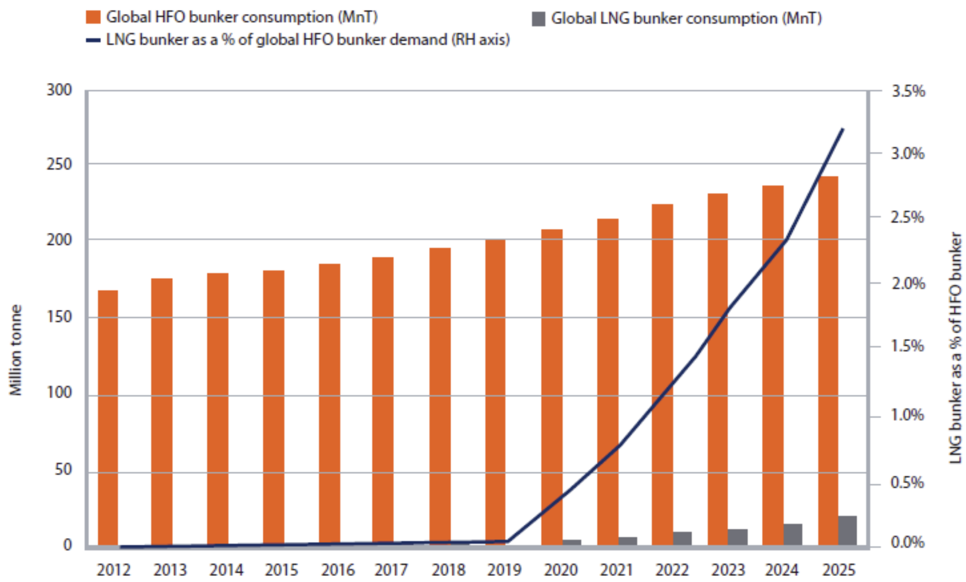

Fig. 3. Global bunker consumption versus LNG bunker demand 2012-2025- base case [11]

Till 2019 the LNG bunker demand is near zero (about 0.1%). Due to future emissions regulations with date enforcement on 2020 it is expected a growth to about 3% of total bunker fuels but still it is a prognosis.

The interest in LNG use will be raise. It needs a small revolution in technology, in people thinking and it will change the marine fuel market but how much? Let's see the next prognosis - global LNG production versus LNG bunker demand 2012-2025- base case.

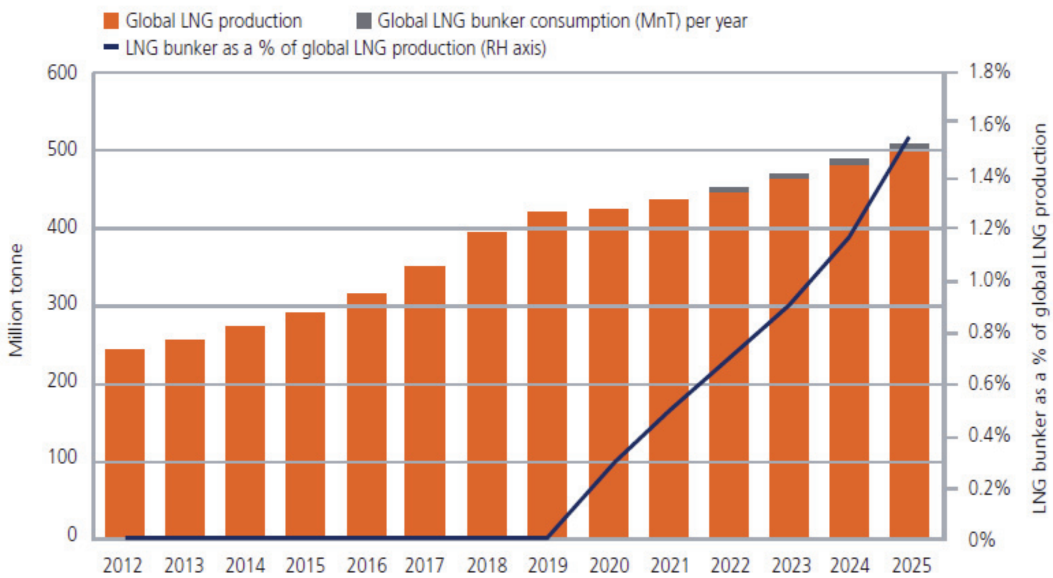

Fig.4. Global LNG production versus LNG bunker demand 2012-2025- base case [11]

The LNG bunker part is now about zero up to about 1.5% in 2025. Is it possible so growth? Maybe yes but many ship-owners, gas suppliers, shipyards and other involving industry would wait for next prognosis. LNG bunker demand is highly dependent on LNG pricing and especially in comparison to other marine fuels and future alternative fuels.

The monitoring of global commercial development of LNG as a fuel is an important factor for forecast. The regulations for the ship design and construction were prepared by classification societies [7,8] and national authorities but there are still in the development. The IMO prepared INTERIM guidelines, by 2014 will be ready new IGF code.

3. LNG barge and small carriers designs for ship bunkering

At first it is a necessary to design, to build and to introduce into exploitation LNG barges or vessels ready for ship bunkering. The process has been started. Small LNG carriers were presented on Fig. 5 and 6. Ms. Anthony Veder (Fig. 6.) was built at Meyer Werft in Germany and in December 2012 was delivered to Dutch owner Anthony Veder Group.

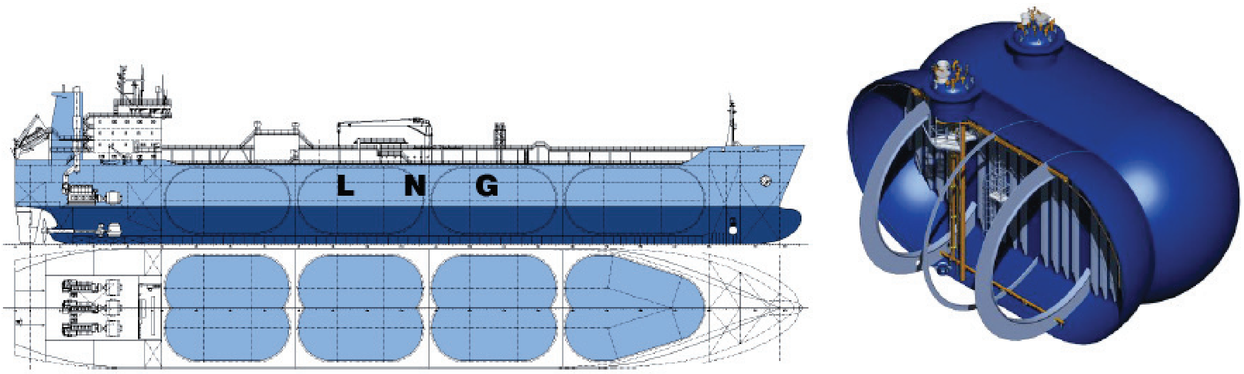

Fig. 5. Small LNG carrier (TGE-Marine design) up to 75000 m^3 [13]

Fig. 6. 15600 m^3 LNG carrier (TGE-Marine design) – delivered December 2012 [13]

The basic requirements for future operations of LNG ship bunkering are as follows:

- the bunker vessel ought to operate alongside during the normal cargo operations (tight time schedule),
- it is needful the regulations and standards for the bunker interface and related operations (are under preparations),
- ESD (emergency shutdown) connections,
- dry-break emergency coupling,
- safe but easy handling of heavy equipment,
- avoid spool pieces/reducers.

The fleet of small LNG carriers and barges are the basic factor for future development of LNG ship bunkering. An example of European existing LNG terminal is presented on Fig. 7. The possibility for LNG ship bunkering is limited due to deficiency above mentioned small LNG carriers. The LNG bunkering process ought to be provided not at LNG terminals but at normal quays during normal cargo operations.

4. Ship conversion to LNG

The case of "Bit Viking" in LNG conversion was described by Mathias Jansson [14]. The main engines of twin screw chemical tanker of 25000 DWT built in 2007 was conversed to dual fuel engine (HFO and LNG). The process lasted 10 weeks from the arrival to dock to entrance into exploitation after gas trials. The two main engines 6L46 were rebuilt to dual fuel (DF) W6LDF type. Engine conversion was completed in only 4 weeks. It was indispensable an assembly of two LNG tanks of 500 m^3 volume each (Fig. 9). It was first LNGPac delivered by Wartsila. There is no additional room, the gas valve unit (GVU) was built in enclosure. The LNG bunkering process of m/v Bit Viking was presented on Fig. 8. The bunkering rate of LNG reached 430 m^3/h, other words the bunkering process lasted a little over 2 hours. The ship autonomy is about 12 days on 80% load on LNG.

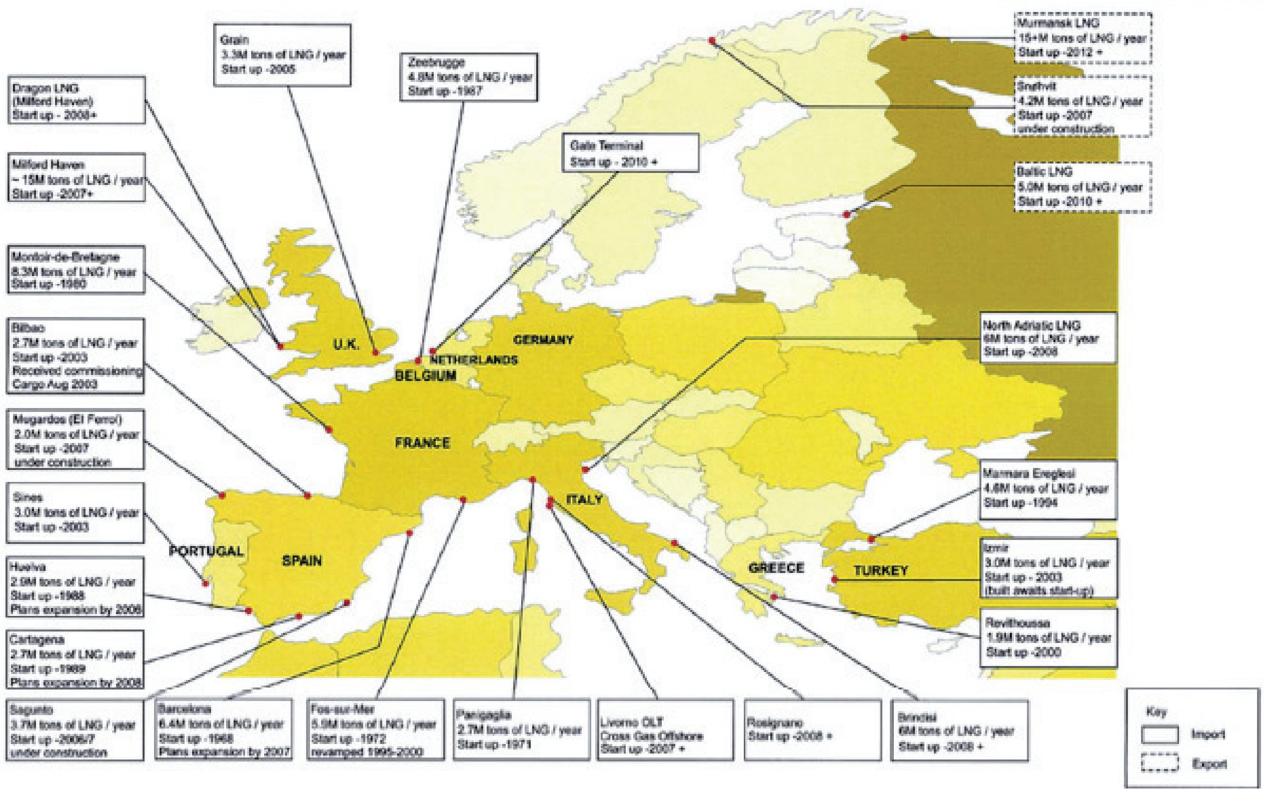

Fig. 7. LNG terminals in Europe [source: world lng map 2006]

The LNG conversion ought to receive "type approval certifies" that gas or dual fuel engine fulfils in principle all currently IMO SOLAS and classification society requirements for use on board ships. Next the equipment used in conversion has the global acceptance and recognition of the quality.

The next conversions will depend on ship-owners decision who will have a look on many factors: the sailing area, the regulations, the environmental taxes or allowances and LNG system elements prices, experiences in exploitation of LNG systems.

5. Final remarks

Using of LNG as a fuel will rapidly increase when the LNG bunkering market is occurred. Marine chief engineers are waiting for a landmark in ship fuelling to break today situation when a few types of fuels are in usage.

Many reasons may have an influence on development the LNG network. It seemed that the fuel of the future will be gas fuels, mainly LNG or CNG, especially on SECA areas. The fuel gas systems for ships are the main drivers. The technical solutions for small LNG transport and LNG as ship's fuel are available. Now is the time for taking advantage of that. The proven safety systems are limiting the risk of LNG operations. Development of bunkering infrastructure is now the main challenge.

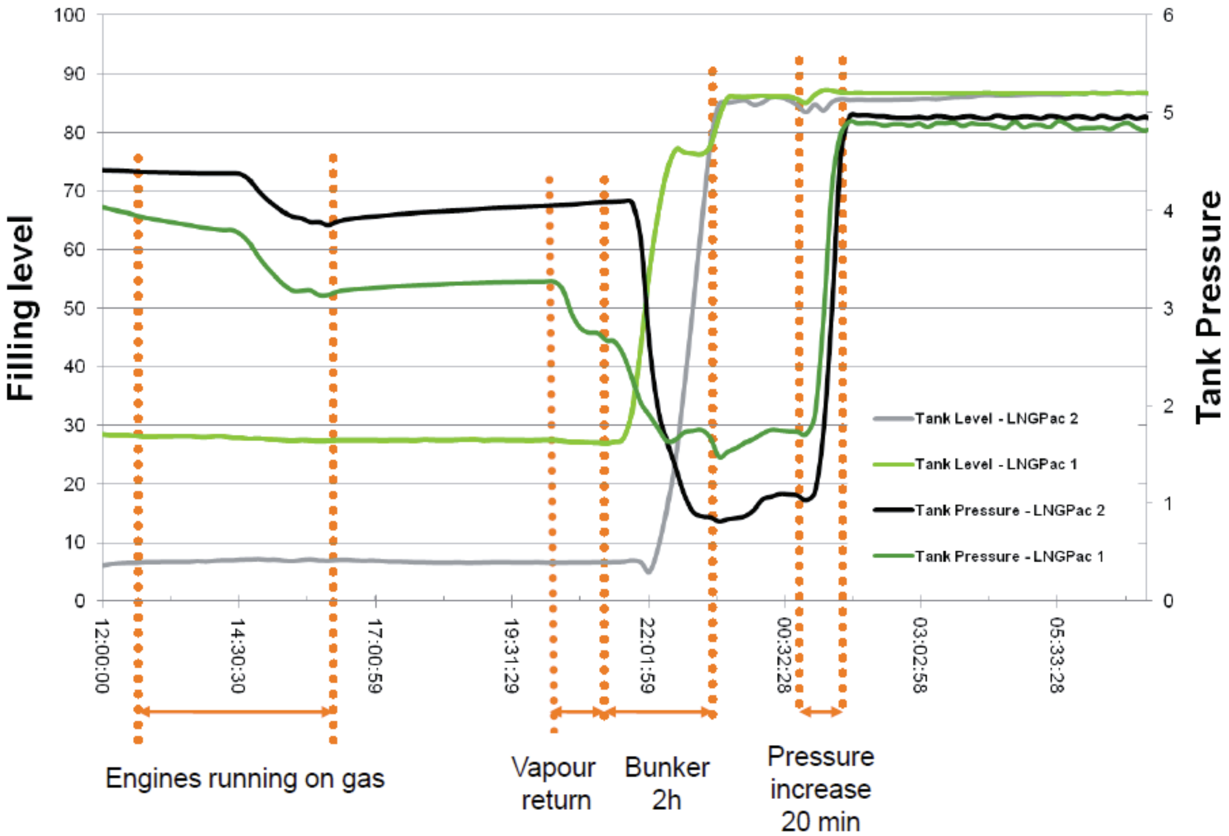

Fig. 8. The diagram of m/v Bit Viking LNG bunkering process at 430 m³/h at Risavika terminal [14]

Fig. 9. The LNG tank 500m³ for m/v Bit Viking [14]

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